Comparative research of the color brightness distortion of the image compressed by DHT

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***Abstract* – The review examines the usage of discrete Hartley transformation (DHT) for the digital image compression. The results of the comparative research of the impact of usage DHT compression on the brightness of the color digital image are provided.**

Keywords – digital image compression, discrete Hartley transformation

Large volumes of graphic data circulate in information and communication systems. The majority of these digital images and videos are characterized with extra-large size. The size of this data type is constantly increasing [1]. Compression is used to reduce the amount of graphic data and it also helps to reduce the amount of memory storage and data transmission resources. Therefore, the development of compression methods for digital images is an actual problem.

An image in its digital representation is a set of matrices, consisting of a fixed number of elements (pixels). Coding of each matrix by transformation enables access to a complex of other matrices (transformant) with the same number of elements. While using the transformations it is very important to ensure that transform coefficients are independent and that image energy is focused in a less amount of coefficients.

Relevant image compression schemes with transformation perform two consecutive operations. The first one includes linear transformation of statistically dependent picture elements into a set of independent components. The second operation includes selection and encoding of the received coefficients. Thus, the majority of errors detected in the process of image decoding is found on the stage of coefficient selection.

Discrete Hartley transformation (DHT) is a very interesting example of the unitary transformation [2], which is characterized as a symmetry between forward and reverse transformations. Its main point is a couple of integral transformations: forward and backward, which are introduced by the function $\mathrm{cas}(\Theta)=\cos(\Theta)+\sin(\Theta)$. Direct and inverse DHT is determined by the following correlations [3]:

$$H(\nu)=N^{-1}\sum_{\tau=0}^{N-1} f(\tau)cas(2\pi\nu\tau/N),$$

$$f(\tau)=\sum_{\nu=0}^{N-1} H(\nu)cas(2\pi\nu\tau/N).$$

Factor N-1 ensures that H(0) equals the mean value of the actual function $f(\tau), \tau=0,1,\dots,N-1$. DHT for two-point, four-point and eight-point vectors is determined by the following expressions:

$$\begin{aligned}&H(0)=(1/2)\,[\,f(0)+f(1)\,],\\&H(1)=(1/2)\,[-f(0)-f(1)\,];\end{aligned}\tag{1}$$

$$\begin{aligned}&H(0)=(1/4)\,[\,f(0)+f(1)+f(2)+f(3)\,],\\&H(1)=(1/4)\,[\,f(0)+f(1)-f(2)-f(3)\,],\\&H(2)=(1/4)\,[\,f(0)-f(1)+f(2)-f(3)\,],\\&H(3)=(1/4)\,[\,f(0)-f(1)-f(2)+f(3)\,];\end{aligned}\tag{2}$$

$$\begin{aligned}&H(0)=(1/8)[\,f(0)+f(1)+f(2)+f(3)+f(4)+\\&+f(5)+f(6)+f(7)],\\&H(1)=(1/8)[f(0)+\sqrt{2}f(1)+f(2)+0+\\&+f(4)-\sqrt{2}f(5)-f(6)-0],\\&H(2)=(1/8)[f(0)+f(1)-f(2)-f(3)+f(4)+\\&+f(5)-f(6)-f(7)\,],\\&H(3)=(1/8)\,[\,f(0)+0-f(2)+\sqrt{2}f(3)-f(4)-\\&-f(5)+f(6)-\sqrt{2}f(7)],\\&H(4)=(1/8)[f(0)-f(1)+f(2)-f(3)+f(4)-\\&-f(5)+f(6)-f(7)],\\&H(5)=(1/8)[f(0)-\sqrt{2}f(1)+f(2)+0-\\&-f(4)+\sqrt{2}f(5)-f(6)+0],\\&H(6)=(1/8)[f(0)-f(1)-f(2)+f(3)\;+\\&+f(4)-f(5)-f(6)+f(7)],\\&H(7)=(1/8)[f(0)+0-f(2)-\sqrt{2}f(3)\;-f(4)+\\&+f(6)+\sqrt{2}f(7)].\end{aligned}\tag{3}$$

Expressions (1-3) primarily consist of addition and subtraction, which are done quite fast by modern microprocessors in comparison to multiplication and division, which indicates a very low computational complexity of DHT.

The analysis of existing transformations show that Hartley transformation with a fast computational algorithm is close to Karhunen-Loeve conversion (KLC), which has the best ability to concentrate maximum power in fewer samples.

Let's review some methods of selecting transformant components: zonal and threshold [3]. If to mark addresses of incoming samples as I_t ($I_t=\{k,l;y_{k,l}\ge 1\}$), and their number as "nt", then it is possible to determine the function of zonal masking $m(k,l)=\begin{cases}1, & k,l\in I_t;\\0, & \text{otherwise}\end{cases}$, which is equal to number one in the area of greatest concentration nt greater values of samples conversion $y_{k,l}$.

During the transforming coding process, the distinguishing and quantization of non-zero elements (only) of the transformed image is done. This method is called zonal coding, which is a nonadaptive way of saving the amount of elements which have the greatest energy.

According to the threshold method, all components of the Y transformant are evaluated, and then just nt number of samples is kept (just samples with maximum amplitude exceeding the threshold). This method is called threshold coding. Addresses of incoming samples are $I_t' = \{(k, l) \mid |y_{k,l}| > K_{trs}\}$, where K_{trs} is the selected threshold.

Thus, zonal coding is a nonadaptive way of saving the amount of elements which have the greatest energy. According to the threshold method, all transformant components are evaluated and then only those that exceed a specified threshold are kept. The method is adaptive as it saves only the elements that are greater for a particular fragment. That is, the process of optimization of selecting coefficients to the local informational structure.

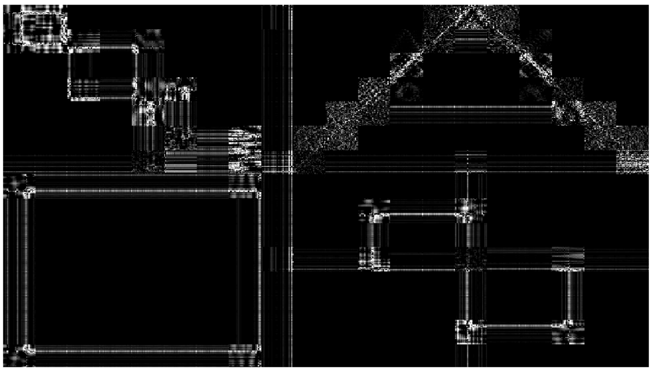

Fig. 1. The result of image recovery error

Let's research the transformant obtained by Hartley transformation. For each image type different values of coding parameters are used, an input image – standard format (4:3) or 640x480 picture elements. Fig. 1 shows the result of image recovery error occurred while using the offered method. These data indicate that the largest recovery error occurs on the edges of the image.

Deviation of brightness values recovered items from the original image are given in Table 1.

TABLE 1

DEVIATION OF BRIGHTNESS VALUES RECOVERED ITEMS FROM THE ORIGINAL IMAGE

Method	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Zonal	0	-5	3	3	-4	2	0	6	-8	10	-1	0
Threshold	-2	-1	2	2	0	-2	0	8	-8	11	1	-2
JPEG	0	0	3	3	-1	-3	0	8	-7	11	-1	-3
Proposed	-1	2	5	2	1	1	-1	-2	-5	6	2	0
Method	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Zonal	0	-5	-2	3	3	-3	0	4	2	-4	1	1
Threshold	0	-6	0	5	2	-4	0	-1	6	-1	-3	2
JPEG	0	-8	1	6	-1	-4	0	-4	7	0	-7	2
Proposed	-1	1	2	3	0	-1	-2	-2	2	0	-1	5
Method	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Zonal	-5	15	-3	-9	6	1	-11	15	-6	3	7	-3
Threshold	-3	7	2	-4	-2	3	-7	5	-3	9	-2	1
JPEG	0	3	4	-2	-6	5	-3	2	4	13	-6	4
Proposed	-4	4	1	-1	0	3	0	2	-4	4	-6	3

A comparative research was done relatively to zonal and threshold methods, and JPEG compression standard. Fig.2 shows the results of the experimental evaluation.

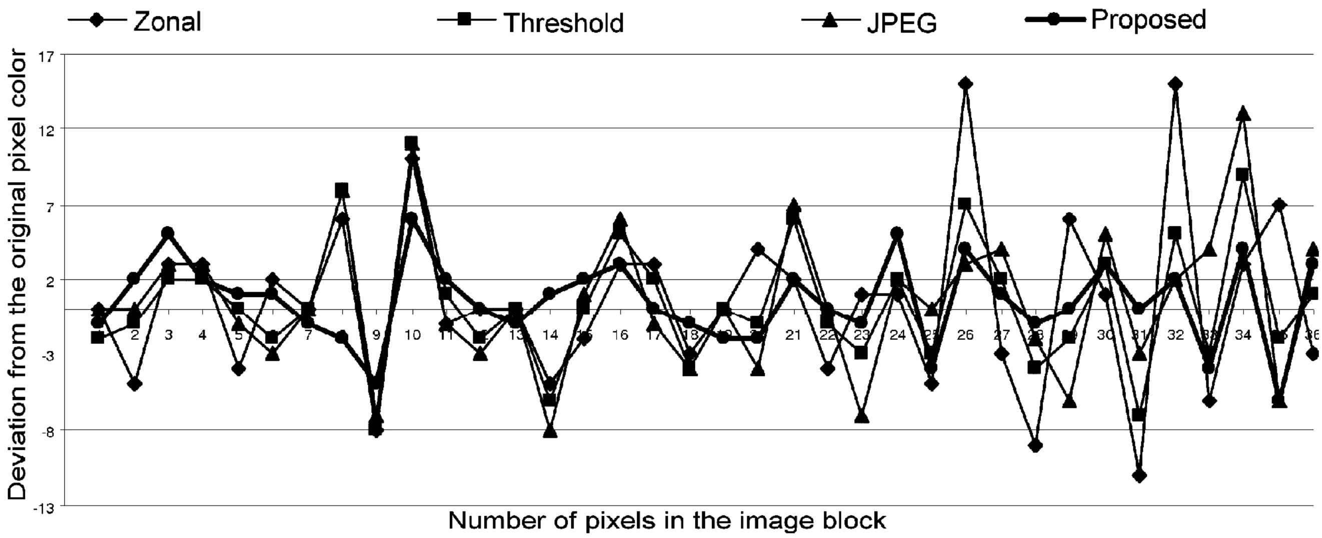

Fig. 2. Brightness distortion (value deviation) of the restored image (compared to the original) using zonal, threshold, JPEG standard and the offered method

Conclusion

Experimentally achieved results show that the errors occurred while using the offered method are based on the errors of the reviewed methods. It indicates a significantly better quality of image reconstruction while using the method of image compression based on the discrete Hartley transformation.

References

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